

Department of Aeronautics and Engineering Mechanics

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Minneapolis, Minnesota

Status Report

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Nonlinear Response of Elastic Shells

Principal Investigator

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1. Enclosed are five (5) copies of a paper entitled "Nonlinear Theory of Elastic Surfaces" which appeared in the Journal of Mathematical Physics, Vol. 7, No. 2, February 1966.

The summary of this work reads:

"The present paper develops a nonlinear theory for the deformation of an elastic surface by assuming the existence of a strain energy function and postulating a principle of virtual work which governs its mechanical behavior. By considering the strain energy function to depend on the first and second order deformation gradients, the field equations and the general constitutive relations are obtained. In addition to the conventional couple stresses, there are shown to exist energetically undetermined double stresses without moment."

The paper presents, therefore, a relatively simple, isothermal, nonlinear theory of shells. It is believed that this theory will be readily amenable to mathematical solution of important physical problems.

This paper was scheduled to appear in January 1966. Actual publication was delayed a month.

2. The results of the February 1966 paper were extended and led to the development of a new, more general and exact nonlinear elastic theory of shells undergoing isothermal deformations. This work was recorded in a paper titled "A Nonlinear Theory of Elastic Directed Surfaces," and was

submitted and accepted for publication in the Journal of Mathematical Physics. We have recently completed our correction of the galley proofs which has contributed to the delay in the appearance of this report. Enclosed are five (5) copies of the corrected proofs of this paper the abstract of which reads:

"The present paper develops a nonlinear theory for the deformation of anelastic directed surface by assuming the existence of a strain energy function and postulating a principle of virtual work which governs its mechanical behavior. The equations of equilibrium and the boundary conditions are shown to involve both the classical stress as well as the double stress. Constitutive equations are derived which give the stress and double stress as functions of a complete set of strain measures which describe the deformation of directed surfaces."

Reprints of the paper have been ordered and will be sent to NASA as soon as they become available.

3. Work continued on the thermodynamic problem in which the surface experiences a high temperature rise. The Helmholtz' free energy function was introduced as well as the entropy density and the heat flux vector. Two postulates which are extremely critical to develop a consistent theory, have been made, namely, an equation of energy balance and an inequality of entropy production. Certain fundamental conceptual difficulties have arisen, among them the inertia terms in our  $R_2$  manifold, which have delayed progress.

Since funds are still available to complete this aspect of our work, we have requested a six months' extension of the termination date of the Grant from April 30, 1966 to October 31, 1966. We believe we will complete the thermo-elastic theory of directed surfaces by the latter date.